APPENDIX L

FISHERY REPORT: *DISSOSTICHUS ELEGINOIDES* HEARD ISLAND (DIVISION 58.5.2)

CONTENTS

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1. Details of the fishery

1.1 Reported catch

The catch limit of *Dissostichus eleginoides* in Division 58.5.2 for the 2006/07 season was 2 427 tonnes (Conservation Measure 41-08) for the period from 1 December 2006 to 30 November 2007. The catch of *D. eleginoides* reported for this division by October 2007 was 1 956 tonnes. Reported catches along with the respective catch limits and number of vessels active in the fishery are shown in Table 1. In Division 58.5.2, the fishery was a trawl fishery from the 1996/97 to the 2001/02 season. In recent seasons the fishery has been prosecuted by both trawlers and longliners. The longline fishery was active from April to September 2007 and the trawl fishery was active throughout the whole season.

Table 1: Catch history for *Dissostichus eleginoides* in Division 58.5.2 (source: STATLANT data for past seasons, and catch and effort reports for current season, WG-FSA-07/10 Rev. 5 and past reports for IUU catch).

Season	Regulated fishery						Estimated IUU catch (tonnes)	Total removals (tonnes)
	Reported effort (number of vessels)	Catch limit (tonnes)	Reported catch (tonnes)					
			Longline	Pot	Trawl	Total		
1989/90	-	-	0	0	1	1	0	1
1991/92	-	-	0	0	0	0	0	0
1992/93	-	-	0	0	0	0	0	0
1994/95	-	297	0	0	0	0	0	0
1995/96	-	297	0	0	0	0	300	3000
1996/97	2	3800	0	0	1927	1927	7117	9044
1997/98	3	3700	0	0	3765	3765	4150	7915
1998/99	2	3690	0	0	3547	3547	427	3974
1999/00	2	3585	0	0	3566	3566	1154	4720
2000/01	2	2995	0	0	2980	2980	2004	4984
2001/02	2	2815	0	0	2756	2756	3489	6245
2002/03	3	2879	270	0	2574	2844	1274	4118
2003/04	3	2873	567	0	2296	2864	531	3395
2004/05	3	2787	621	0	2122	2744	265	3009
2005/06	3	2584	659	68	1801	2528	74	2602
2006/07*	2	2427	618	0	1338	1956	0	1956

* Catch returns for 2006/07 not complete. Fishing season ends 30 November.

2. The spatial and temporal structure of the fishing for *D. eleginoides* is summarised in Table 2. The Working Group noted that a minor amount of longline fishing has occurred in trawl ground B to date and that some longline fishing occurs in areas other than the known grounds, but these are not appreciable at this stage. The pot fishery has only been experimental to date (72 tonnes).

Table 2: Spatial and temporal structure of the fishing activities for *Dissostichus eleginoides* in Division 58.5.2 including summary codes for the different elements of the fishery. f – fishery; s – season.

Gear type	Season			
	Approximate area (km^2)	Prior to longline	Longline	Post longline
Survey	85 694	-	f1	-
Trawl ground B	442	f2_s1	f2_s2	f2_s3
Trawl ground C	2 033	f3_s1	f3_s2	f3_s3
Longline ground A	16 678	-	f4_s2	-
Longline ground C	2 033	-	f5_s2	-
Longline ground D	90 625	-	f6_s2	-

1.2 IUU catch

3. There was no evidence of IUU fishing in Division 58.5.2 in 2006/07 (Table 1).

1.3 Size distribution of catches

4. Catch-weighted length frequencies are illustrated in Figures 1 (trawl fishery) and 2 (longline fishery). The Working Group noted that the modal size of fish caught in the longline fishery was greater than that in the trawl fishery. The difference in selectivities between trawl and longline sub-fisheries in Division 58.5.2 was estimated in WG-FSA-06/64. This work showed that longline gear is more able to catch older fish (>25 years), than trawl gear, which has high selectivity for 6-year-old fish, effectively declining to zero for fish older than 20. The length-frequency distribution for the longline fishery will therefore have larger fish because of gear selectivity, as well as the longline fishery occurring in deeper water where toothfish tend to be larger.

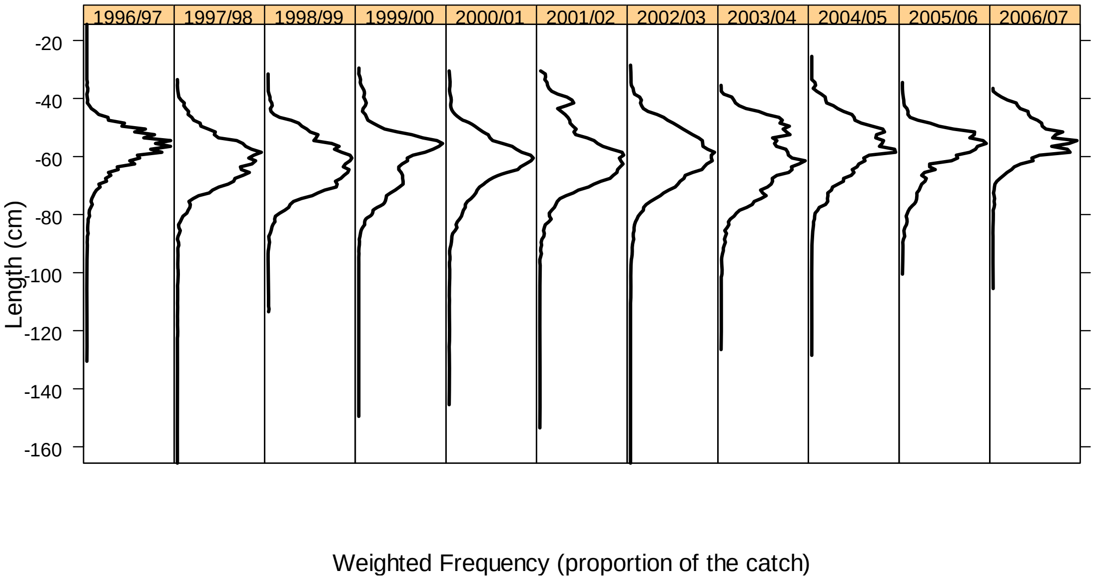


Figure 1: Catch-weighted length frequencies for *Dissostichus eleginoides* caught by trawl in Division 58.5.2 (source: observer, fine-scale and STATLANT data).

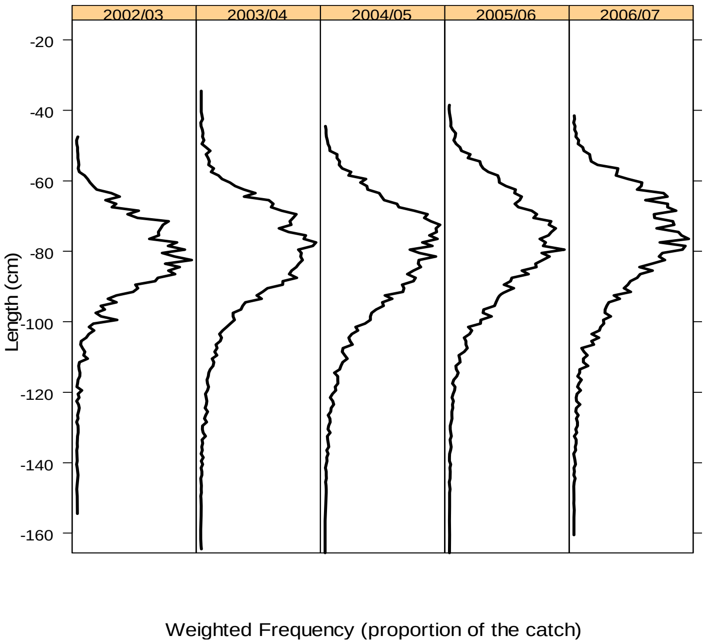


Figure 2: Catch-weighted length frequencies for *Dissostichus eleginoides* caught by longline in Division 58.5.2 (source: observer, fine-scale and STATLANT data).

2. Stocks and areas

5. *Dissostichus eleginoides* occurs throughout the Heard Island and McDonald Islands Plateau, from shallow depths near Heard Island to at least 1 800 m depth around the periphery of the plateau. Random stratified trawl surveys have been conducted since 1990 with survey designs described in detail in WG-FSA-06/44 Rev. 1. Younger fish (less than about 600 mm TL) predominate on the plateau in depths less than 500 m, but no areas of local abundance have been discovered. As fish grow, they move to deeper waters, and are recruited to the trawl fishery on the plateau slopes in depths of 450 to 800 m. Here there are several areas of local abundance that constitute the main trawling grounds where the majority of fish caught are between 500 and 750 mm TL (Figure 1). Older fish are seldom caught in the trawl fishery, and it is assumed that they move into deeper water (>1 000 m depth) where they are caught by the longline fishery. This fishery mostly operates between 1 000 and 1 500 m depth and catches larger fish than in the trawl fishery (Figure 1), but few fish are >1 000 mm TL.

6. Genetic studies have demonstrated that the *D. eleginoides* population at Heard Island and McDonald Islands is distinct from those at distant locations such as South Georgia and Macquarie Island (Appleyard et al., 2002), but that within the Indian Ocean sector there appears to be no distinction between fish at Heard, Kerguelen, Crozet or Marion/Prince Edward Islands based on genetic studies (Appleyard et al., 2004). This, combined with results from tagging data which show movement of some fish from Heard Island to Kerguelen and Crozet Islands (Williams et al., 2002; WG-FSA-07/48 Rev. 1), suggests that a metapopulation of *D. eleginoides* may exist in the Indian Ocean sector (WG-FSA-03/72).

3. Parameters and available data

3.1 Parameter values

Fixed parameters

7. The von Bertalanffy growth parameters from the 2005 assessment were replaced in the 2006 assessment and for this year by a mean length-at-age vector based on the von Bertalanffy growth curve with an early age adjustment for fish less than five years as described in Candy et al. (2007). This model is based on validated age data (WG-FSA-05/60 and 05/61) and provides the best fit to length-at-age data from the trawl fishery. The Working Group recalled that estimates of length-at-age for fish greater than 20 years of age would improve with data from the longline fishery. As adopted by WG-FSA-06 for long-term yield calculation (SC-CAMLR-XXVI, Annex 5, Appendix N, Table 14(b)), the CASAL model was restricted to ages 1 to 35, rather than 1 to 50 as in previous assessments, due to the uncertainty about predicted mean length-at-age for ages above 35 resulting from extrapolation well outside the data range required for these older ages.

8. Current assessments of this stock assume a natural mortality of 0.13. As a consequence of the slower growth estimated for *D. eleginoides* in this area, the Working Group agreed that natural mortality was unlikely to be as great as 0.2 year^{-1}. As for the 2006 assessment, the default value of M, 0.13 year^{-1}, has been adopted for this year pending new analyses and/or the general considerations on natural mortality of this species.

9. The input parameters used in the assessment are included in Table 3.

Table 3: Input parameters for the assessment of *Dissostichus eleginoides* in Division 58.5.2.

Component	Parameter	Value	Units
Natural mortality	*M*	0.13	y^{-1}
Length-at-age (age in parentheses)	(1) 251.0 (2) 307.5 (3) 367.3 (4) 430.4 (5) 497.0 (6) 547.5 (7) 594.8 (8) 641.1 (9) 686.5 (10) 730.9 (11) 774.5 (12) 817.1 (13) 858.9 (14) 899.9 (15) 940.0 (16) 979.3 (17) 1017.8 (18) 1055.5 (19) 1092.5 (20) 1128.7 (21) 1164.1 (22) 1198.8 (23) 1232.9 (24) 1266.2 (25) 1298.9 (26) 1330.9 (27) 1362.2 (28) 1392.9 (29) 1423.0 (30) 1452.5 (31) 1481.3 (32) 1509.6 (33) 1537.3 (34) 1564.5		(year) mm
CV of length-at-age	CV_{VB}	0.1	
Length to mass	'*a*'	2.59E-09	mm, kg
Length to mass	'*b*'	3.2064	
Maturity (age based)	(11) 0.0 (12) 0.1667 (13) 0.3333 (14) 0.5000 (15) 0.6667 (16) 0.8333 (17) 1.0000		

10. Recruitment is modelled without assuming a stock-recruitment relationship. Variability in recruitment is estimated from the output of the CASAL integrated assessment and is determined largely from the variability across years in estimated year-class strength.

Recruitment surveys

11. Surveys of young toothfish have been undertaken since 1990 (Table 4). The survey design was consolidated in 2001 with the distribution of stations undertaken during a survey revised in 2003 (WG-FSA-04/74).

Table 4: Details of trawl surveys considered for estimating the abundance of juvenile *Dissostichus eleginoides* in waters less than 1 000 m deep in Division 58.5.2. AA = RV *Aurora Australis*, SC = FV *Southern Champion*, DT = demersal trawl.

Survey year	Group	Date	Vessel	Gear	Original design area (km^2)	Area following reassignment (km^2)	Hauls	Catch (tonnes)
1990	3	May	AA	DT	97 106	53 383	59	16
1992	4	Feb	AA	DT	55 817	38 293	49	3
1993	5	Sep	AA	DT	71 555	53 383	62	12
1999	2	Apr	SC	DT	84 528	80 661	139	93
2000	6	May	SC	DT	39 839	32 952	103	9
2001	1	May	SC	DT	85 170	85 694	119	45
2002	1	May	SC	DT	85 910	85 694	129	35
2003	7	May	SC	DT	42 280	42 064	111	13
2004	1	May	SC	DT	85 910	85 694	145	65
2005	1	May	SC	DT	85 910	85 694	158	21
2006	1	May	SC	DT	85 694	85 694	158	12
2007	1	July	SC	DT	85 694	85 694	158	12

12. A report of the methodology and results of the Australian research survey in 2007 was tabled in WG-FSA-07/46, along with the methods used in the survey. Australia undertook a trawl survey of Division 58.5.2 in June–July 2007 to estimate the density of juvenile toothfish (WG-FSA-07/46). The survey used the same design as in the 2005 survey, with the exclusion of hauls in Shell Bank which are intended for assessing *Champsocephalus gunnari* abundance (Table 5).

Table 5: Dates and number of planned and completed hauls for each stratum in the 2007 random stratified trawl survey.

Stratum	Dates sampled	Area (km^2)	No. hauls allocated	No. hauls completed	No. valid hauls
Ground B	28 June–3 July	480.8	20	22	22
Gunnari Ridge	2–5 July	520.7	18	18	18
Plateau Deep East	20–24 June	13 120	30	30	30
Plateau Deep Northeast	28–30 June	15 090	15	15	15
Plateau Deep Southeast	3–4 July	5 340	10	10	9
Plateau Deep West	26–31 July	13 370	10	10	10
Plateau North	27–31 July	15 170	15	15	15
Plateau Southeast	4–21 July	10 404	30	30	29
Plateau West	5–7 July	10 440	10	10	10
All Strata	28 June–31 July	83 935.5	158	160	158

13. The allocation of stations to strata in the historical surveys was reviewed in 2006 (WG-FSA-06/44 Rev. 1). The Working Group agreed to the reassignment of stations according to the stratification of the survey design finalised in 2003 and noted the following groupings of surveys:

- Group 1 – the core surveys with the most reliable estimates of the abundance of young fish in the vicinity of Heard Island and McDonald Islands in waters less than 1 000 m deep in May–June. Random stratified trawl surveys undertaken by a commercial vessel – 2001, 2002, 2004, 2005, 2006, 2007.

- Group 2 – the first large-scale random stratified trawl survey for *D. eleginoides* in the region taking into account deep water but with an emphasis on fishing grounds. The survey was undertaken by a commercial vessel in April 1999.

- Group 3 – the first survey in the region, undertaken by the RV *Aurora Australis* – autumn 1990.

- Group 4 – the second survey in the region, undertaken by the RV *Aurora Australis* – winter 1992. This survey is considered incomplete for the purposes of estimating abundance of juvenile toothfish.

- Group 5 – the third survey in the region, undertaken by the RV *Aurora Australis* – spring 1993.

- Group 6 – the second survey in the region undertaken by a commercial vessel – 2000. This survey is considered incomplete for the purposes of estimating abundance of juvenile toothfish.

- Group 7 – a survey undertaken by a commercial vessel but not sampling all strata – 2003.

14. The Working Group confirmed that the bootstrap resampling procedure for estimating annual abundance by length bin and the corresponding coefficients of variation used at WG-FSA-06 is preferred over the Aitchison delta lognormal method (WG-FSA-06/64).

Tagging studies

15. A tagging study has been undertaken at Heard Island since 1998 (Williams et al., 2002). Numbers of tag releases and recaptures are shown in Tables 2 and 3 of WG-FSA-07/48 Rev. 1 and are given below in Table 6. It is anticipated that these data will provide important inputs to future assessments.

16. WG-FSA-06/64 described the methods estimating the tag shedding rate, tag detection probability and potential overdispersion of scanned fish in a tagging study.

17. The Working Group noted that the tagging program has been largely restricted to the main trawl ground B and is likely to underestimate the abundance of fish of this age/length range. At present, the assessment is unable to accommodate the small spatial extent of the program and the limited mixing from this ground to the other areas. These data are, therefore, not utilised in the integrated assessment.

18. The rate of tagging in other fishing grounds has been increased to broaden the area covered by the tagging program.

Table 6: Fishing ground of release and recapture for *Dissostichus eleginoides* in Division 58.5.2. Excludes recaptures outside the division. Ground B corresponds to CASAL fishery 2, Ground C corresponds to CASAL fisheries 3 and 5, Ground D corresponds to CASAL fishery 6 and Survey corresponds to fishery 1 in WG-FSA-06/64.

Recapture source	Recaptures by release source						Total
	Ground A	Ground B	Ground C	Ground D	Other	Survey	
Ground A	13	-	-	-	-	-	13
Ground B	-	2 283	5	6	27	41	2 362
Ground C	-	2	604	4	8	71	689
Ground D	-	4	8	19	-	1	32
Survey	1	24	-	-	3	1	29
Other	-	1	1	-	-	4	6
Total recaptures	14	2 314	618	29	38	118	3 131
Total releases	659	8 470	3 244	692	807	1 318	15 190

Commercial catch–length composition

19. Random length samples were obtained from commercial catches and binned by observers in 10 mm bins. For use in the assessment, these length-frequency data were aggregated into 100 mm bins. The length distributions are given as a proportion of catch in 100 mm length bins from 300 to 1 900 mm along with the associated sample size.

20. WG-FSA-06/64 described the methods for deriving these length distributions using a bootstrap procedure and WG-SAM-07/7 and WG-FSA-07/53 Rev. 1 describe the method used for accounting for over-dispersion of the length-frequency data relative to a multinomial distribution by estimating an effective sample size for each distribution.

Standardised CPUE series

21. The method for standardising catch-and-effort time series data described in Candy (2004) was used to provide a catch-per-unit-effort (CPUE) series for each of the main trawl grounds (Grounds B and C) up to and including 2007 and these were used as a series of relative abundance observations in CASAL. The catchability constant (*q*_CPUE), treated as ‘relative’ observations, is an estimated parameter calculated separately for each of the two CPUE series.

4. Stock assessment

4.1 CASAL model structure and assumptions

22. The CASAL population model used in the assessment of toothfish in Division 58.5.2 was a combined sex, single-area, three-season, multi-fishery model. The annual cycle was defined in three seasons: 1 December–30 April, 1 May–30 September, 1 October–30 November. Mortality and growth occurred uniformly over the year. Fisheries were distributed in these seasons according to the spatial and temporal structure of the fisheries in

Table 2. Spawning was timed to occur on 1 July. The time series for the assessment was 1982 to 2007 with future projections for another 35 years. The initial age structure assumed in the assessment was for a constant recruitment at equilibrium. No stock-recruitment relationship was assumed. All fisheries were modelled with either a double-normal plateau or double-normal age-based selectivity function with the different selectivities for each gear x area combination. Selectivities were assumed to remain constant across seasons with the exception of the Ground B trawl fishery which was estimated to have different selectivity parameters for the late season (s3) compared to the combined early seasons (s1, s2). In addition, for this fishery separate selectivity parameters were estimated for 2006 and 2007 catches due to the generally smaller size of fish caught in these recent seasons compared to previous seasons. In WG-FSA-SAM-06/14 and WG-FSA-06/64 the coefficient of variation, CV_{VB}, for the normal distribution for length-at-age, required to convert length frequencies to age frequencies in CASAL, was obtained independently of CASAL from the fit of the von Bertalanffy growth model to length-at-age data (Table 3) (i.e. estimated parameter σ in Table 1 of Candy et al., 2007). In order to investigate the sensitivity of predictions of age structure to CV_{VB}, this parameter was estimated using CASAL.

Model estimation

23. Analyses were undertaken using a point estimate Bayesian analysis (MPD: maximum posterior density). Exploration of uncertainty in parameter estimates, and its impacts on estimates of yield, used a multivariate normal (MVN) approximation based on the covariance matrix (e.g. WG-FSA-07/53). Non-informative (i.e. uniform) priors were used for all parameters. The MCMC method was not adopted for this assessment due to the problems identified in WG-FSA-SAM-06/14 of unacceptably high autocorrelation in MCMC samples even after a long burn-in and very heavy ‘thinning’ of the sequence of MCMC samples. Until improvements can be made in the application of the MCMC method in the ability to obtain independent samples from the posterior distribution of the parameters, the MVN method is recommended for this assessment. The MVN method is guaranteed to draw independent samples based on the MPD estimates and the Hessian matrix. Additionally, given that uniform priors are used for all parameters, the need to implement an MCMC sampling approach is not obvious since the validity of the quadratic approximation of the likelihood surface for an appropriately parameterised model is well established.

Observation assumptions

24. Numbers-at-length for each survey were used as the primary observations. Observation error was incorporated by using the CV estimates from the bootstrap procedure. These were applied as lognormal errors in the likelihood. Survey Group 1 was assumed to be the most accurate in estimating abundance of young fish and was assumed to have a catchability q = 1. The other survey groups each had a q estimated with the 1990 and 1993 surveys considered to have the same catchability.

25. The catch proportions-at-length data were fitted to the model-expected proportions-at-length composition using a multinomial likelihood with effective sample sizes calculated according to the method described in WG-FSA-07/53 Rev. 1.

26. CPUE indices were assumed to be relative mid-season vulnerable biomass indices with an associated catchability constant *q*. A lognormal likelihood was used for the CPUE indices. Observation error was accounted for by using the CV estimates from the GLMM standardisation described in Candy (2004).

<u>Process error and data weighting</u>

27. Observations were primarily weighted using estimates of effective sample sizes and CVs. Process error of 0.1 was added to all surveys other than Survey Group 1, where it was set to zero, as was the case for the two CPUE series. The iterative CASAL estimation/process error procedure was not used since systematic lack of fit (SLOF) for Survey Group 1 could not be adequately accounted for even after the generic SLOF model was fitted (WG-FSA-07/53 Rev. 1). This meant that the iterative process error procedure gave an unacceptably low weight to the Survey Group 1 relative to the catch-at-length data in the fit when lack of fit was attributed as purely process error. Therefore process error was set to zero with the exception noted above for the survey groups.

<u>Penalties</u>

28. Two types of penalties were included within the model. First, the penalty on the catch constrained the model from returning parameter estimates where the population biomass was such that the catch from an individual year would exceed the maximum exploitation rate. Second, an increasing penalty was applied according to the degree to which the mean of the vector of estimated year class strengths deviated from 1.

<u>Priors</u>

29. The parameters estimated by the model, their priors, starting values for the minimisation, and their bounds are given in Table 7. Uniform priors were chosen that are non-informative given CASAL's Bayesian implementation.

<u>Yield calculations</u>

30. Yield estimates were calculated by projecting the estimated current status for each model under a constant catch assumption, using the rules:

1. Choose a yield, γ_1, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 35-year harvesting period is 10% (depletion probability).

2. Choose a yield, γ_2, so that the median escapement at the end of a 35-year period is 50% of the median pre-exploitation level.

3. Select the lower of γ_1 and γ_2 as the yield.

31. Random recruitments for the projection begin in 2006 and are derived from a lognormal recruitment function where mean recruitment is R_0 for the trial and recruitment variability was estimated from the fit of a linear mixed model (LMM) to the MVN sample of historic recruitments (1983 to 2005). This variability was estimated after a two-year running mean smoother of the historic recruitments was applied with the log of these means fitted by the LMM. The estimates of sigma_r (σ_R) and rho (ρ) (i.e. standard deviation and autocorrelation of log of recruitments) required by CASAL's lognormal random recruitment facility were 0.925 and 0.361 respectively.

Table 7: Number (*N*), start values, priors and bounds for free parameters estimated for *Dissostichus eleginoides* in Division 58.5.2.

Parameter		*N*	Description	Prior	Lower bound	Upper bound	Start values
B_0		1		Uniform	50 000	250 000	100 000
YCS		22	1983–2004	Uniform	0.001	100	1
CV_{VB}		1	CV of length-at-age	Uniform	0.05	0.15	0.1
Selectivities – surveys	S_L	11	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f2_s3, f2_s2r, f3, f5, f6	Uniform	1	10	1,1,1,1,1 1,1,1,1,3,3
	A_1	11	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f2_s3, f2_s2r, f3, f5, f6	Uniform	2	20	4,4,4,4,4 4,4,4,3,6,6
	a_2	6	Survey groups 1, 2, 5 Fisheries f3, f5, f6	Uniform	0.02	20	2,4,4 4,7,7
	S_U	11	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f2_s3, f2_s2r, f3, f5, f6	Uniform	1	12	6,4,7.5,4,7.5 7.5,7.5,7.5,4,8,8
Survey group *q*		3	1999 survey 1990/1993 surveys 2003 survey	Uniform	1e-6	1 000	-
CPUE *q*		2	Trawl ground B Trawl ground C	Uniform	1e-6	1 000	-

32. For a given trial, the pre-exploitation median spawning stock biomass is derived as the median of spawning biomass estimated from 1 000 age structures drawn from lognormally distributed recruitments.

33. The future catch was divided amongst the fisheries according to the recent catch history as well as consideration of the expected trends in the use of different grounds. The following ratios were used:

Trawl ground B – season 1	0.36
Trawl ground B – season 2	0.30
Trawl ground C – season 2	0.06
Longline ground A – season 2	0.04
Longline ground C – season 2	0.08
Longline ground D – season 2	0.16.

4.2 Model estimates

34. MPD estimates of the key parameters for the different scenarios are shown in Tables 8 and 9.

Table 8: Results of assessments of stock status of *Dissostichus eleginoides* in Division 58.5.2 using CASAL. B_0 is the MPD estimate of the pre-exploitation median spawning biomass, CV_{VB} is the coefficient of variation for length-at-age, SSB status 2007 is the ratio of the CASAL prediction of SSB in 2007 to B_0, and R_0 is the MPD estimate of mean age-1 recruitment prior to exploitation (1981).

Model	Description	B_0 (tonnes) (SE)	CV_{VB} (SE)	SSB status 2007	R_0 (million)
a2-ess	Model *a1-50-notag-cl* in WG-FSA-06/64 + refinements	125 219 (5806)	0.0977 (0.0008)	0.725	4.538

Table 9: Estimates of selectivity parameters in Survey Group 1 and catchability of the other survey groups in assessments of stock status of *Dissostichus eleginoides* in Division 58.5.2 using CASAL.

Model	Description	Selectivity parameter estimates Survey Group 1 (SE)				Survey group q estimate[a]			
		S_L	S_U	a_1	a_2	SG3 (1990)	SG5 (1993)	SG2 (1999)	SG7 (2003)
a2-ess	Model *a1-50-notag-cl* in WG-FSA-06/64 + refinements	0.024 (0.002)	4.586 (0.151)	2.465 (0.041)	1.839 (0.326)	0.304	0.304	3.468	0.843

[a] Catchability q set to 1 for Survey Group 1 (2001, 2002, 2004, 2005, 2006, 2007).

35. Figure 3 shows the fit to the Survey Group 1 (SG1) abundance data. Fitted values in the figure show a consistent underestimation of abundance for length bins that contain most of the fish, indicating that the abundance of young fish in other datasets is not as high as that observed in the surveys. Figure 4 shows the fit in that model for the remaining 'single-year' survey groups. The estimate of q obtained for each of the early surveys (Table 9) shows that

the 1999 survey (SG2) was likely to be overestimating the abundance of recruits while the other surveys (1990, 1993 and 2003) were underestimates.

36. Figures 5 and 6 show the fit to the commercial length-frequency data for the two main trawl fisheries (Grounds B and C) for the main fishing season (s2). Figure 7 shows the fit to the longline fishery in Ground C. The corresponding graph in Figure 8 shows the fitted SLOF trend. The smooth quadratic trends across years and length bins show significant deviation from the zero line. The scale of the deviations in Figure 8 corresponds to the linear predictor scale for the Poisson/log link generalised linear model (GLM).

37. Figures 9 and 10 show the standardised CPUE series versus the fitted trend from the CASAL model for each of the trawl grounds respectively. Note that the standardised CPUE series in each case was obtained from the haul-by-haul data combined across all three CASAL seasons based on the standardisation model given by Candy (2004) and updated using data up to and including 2007. The contribution to the objective by the CPUE data was relatively small in each case due to the generally large CVs of the standardised estimates.

38. Figure 11 shows the fitted double-normal-plateau and double-normal selectivity curves for the survey groups and the commercial fisheries. These curves show the distinct differences in how the surveys, trawl and longline activities overlap with the stock, notably that the surveys observe the youngest fish (less than age 5), the trawl fishery concentrates on larger but pre-adult fish and the longline fishery concentrates on larger fish again including mature fish. The notable exception is for the last two fishing seasons in trawl ground B for which the fitted selectivity function (*Sel_f2_s2r*) indicates that fish younger than 5 years have been selected.

39. Figure 12 shows the estimated historical recruitment series using year random effect estimates obtained from the fit of the LMM to the log of number of age-1 recruitments for size-1 000 sample from the MVN distribution for the set of estimated parameters when processed through CASAL's projection procedure. Each of the yearly values and two-year running mean values for numbers of recruits were fitted by an LMM to the logarithm of these values. For the yearly values, the estimate of yearly process error σ_R^2 (sigma_*r* = σ_R) and estimate of the first order auto-regression parameter (rho = ρ) were 3.320 (SE = 0.978) (i.e. σ_R = 1.822) and ρ = –0.089 (SE = 0.007). For the two-year running mean values, the corresponding estimates were 0.855 (SE = 0.258) for the yearly process error σ_R^2 (i.e. σ_R = 0.925) and 0.361 (SE = 0.006) for the 1st order auto-regression parameter respectively.

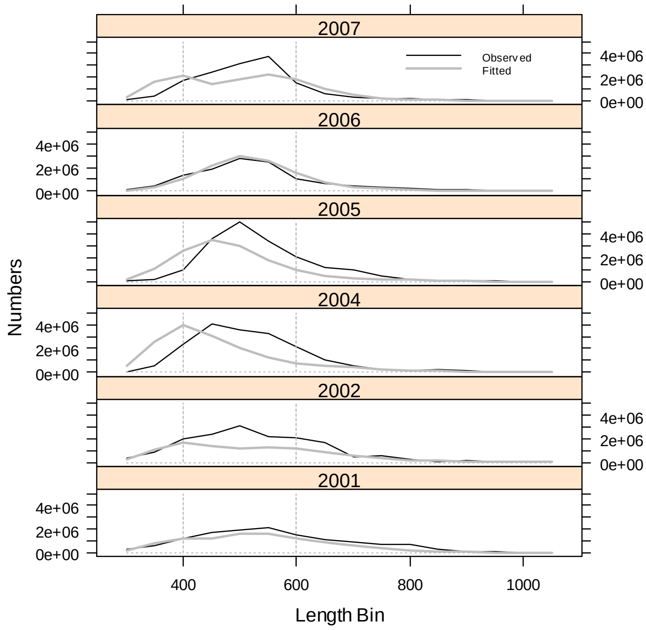


Figure 3: Model fits to Survey Group 1 abundance data with reference lines at 400 and 600 mm.

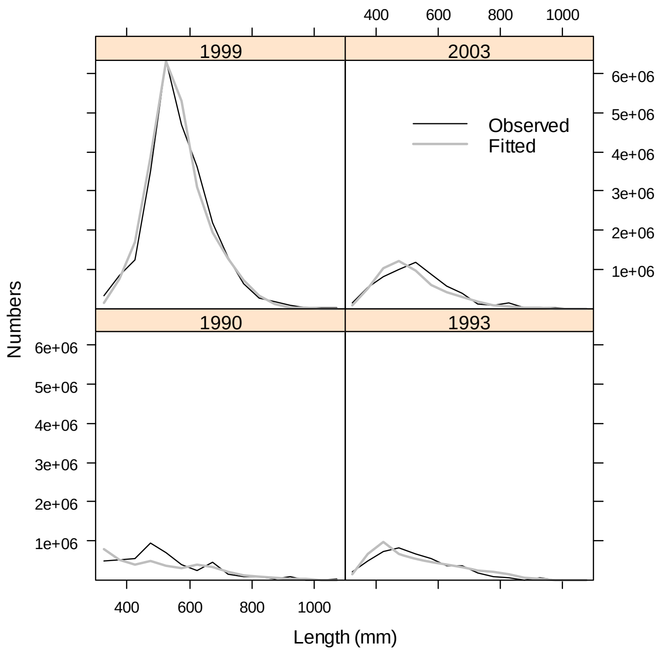


Figure 4: Model fits to Survey Groups 3, 5, 2 and 7 data – comparison of observed (black line) and expected (grey line) numbers-at-length for Survey Groups 3 (1990), 5 (1993), 2 (1999) and 7 (2003).

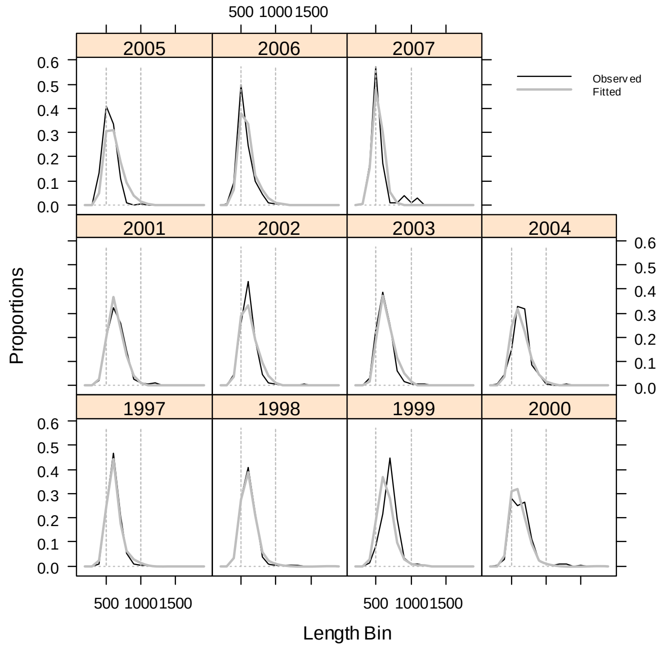


Figure 5: Model fits to catch-at-length proportions for trawl ground B, season 2 (Fishery f2_s2) with reference lines at 500 and 1 000 mm.

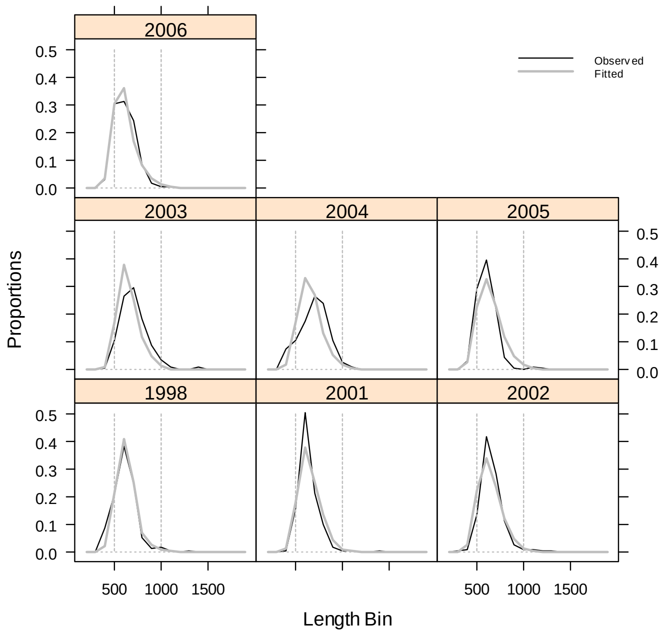


Figure 6: Model fits to catch-at-length proportions for trawl ground C, season 2 (Fishery f3_s2) with reference lines at 500 and 1 000 mm.

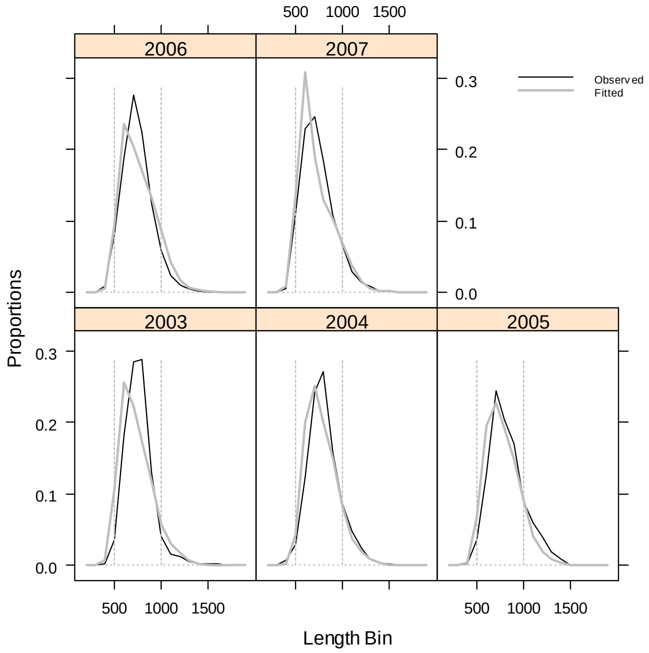


Figure 7: Model fits to catch-at-length proportions for longline ground C, season 2 (Fishery f5_s2) with reference lines at 500 and 1 000 mm.

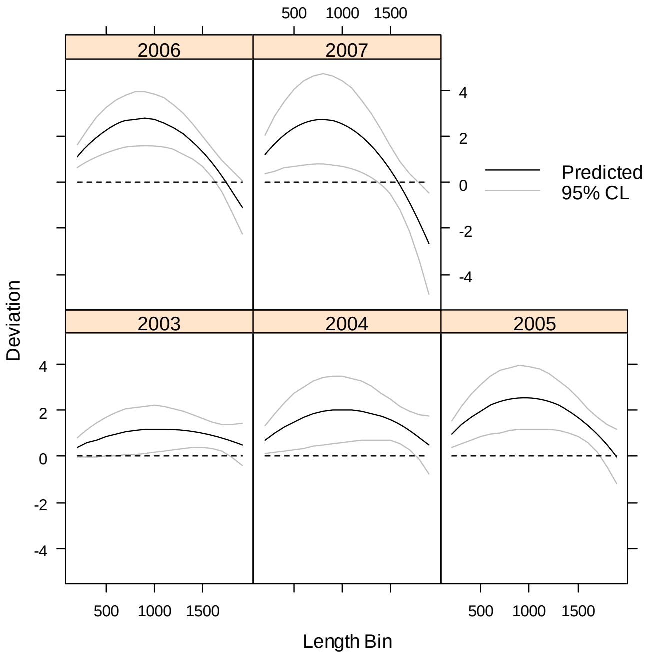


Figure 8: Trend lines from systematic lack-of-fit (SLOF) model for catch-at-length proportions longline ground C, season 2 (Fishery f5_s2).

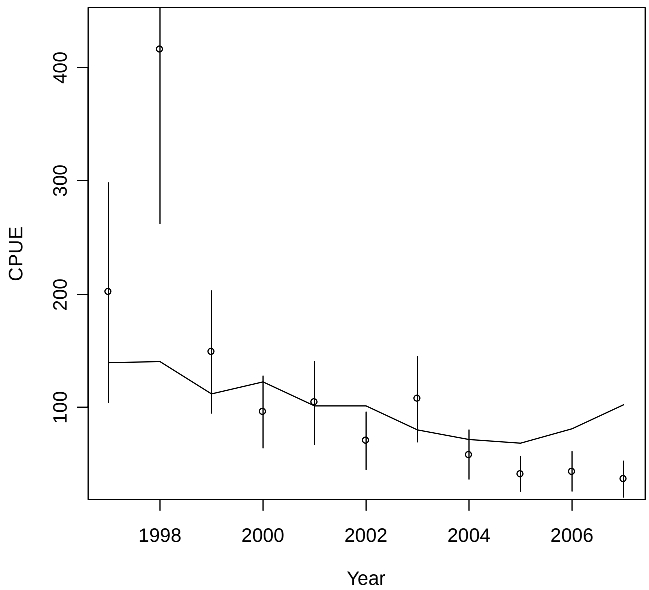


Figure 9: Estimated CPUE series from the GLMM model for trawl ground B (f2) (circles) with bars corresponding to ± one standard error of the estimate and the fitted series (line).

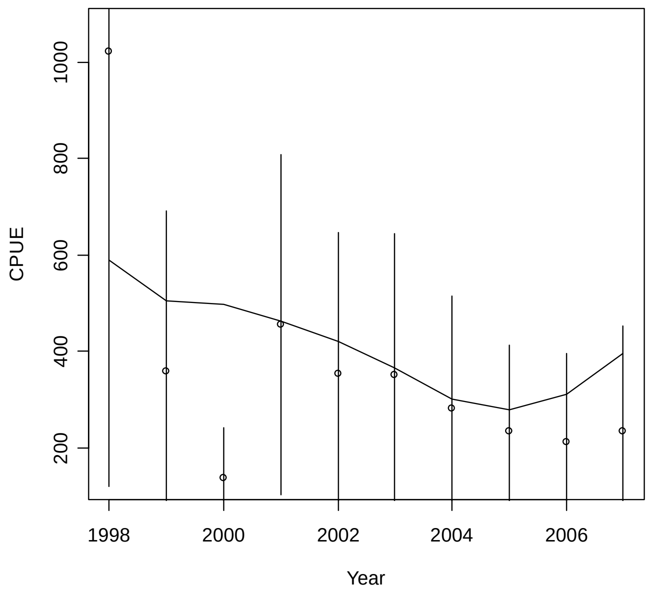


Figure 10: Estimated CPUE series from the GLMM model for trawl ground C (f3) (circles) with bars corresponding to ± one standard error of the estimate and the fitted series (line).

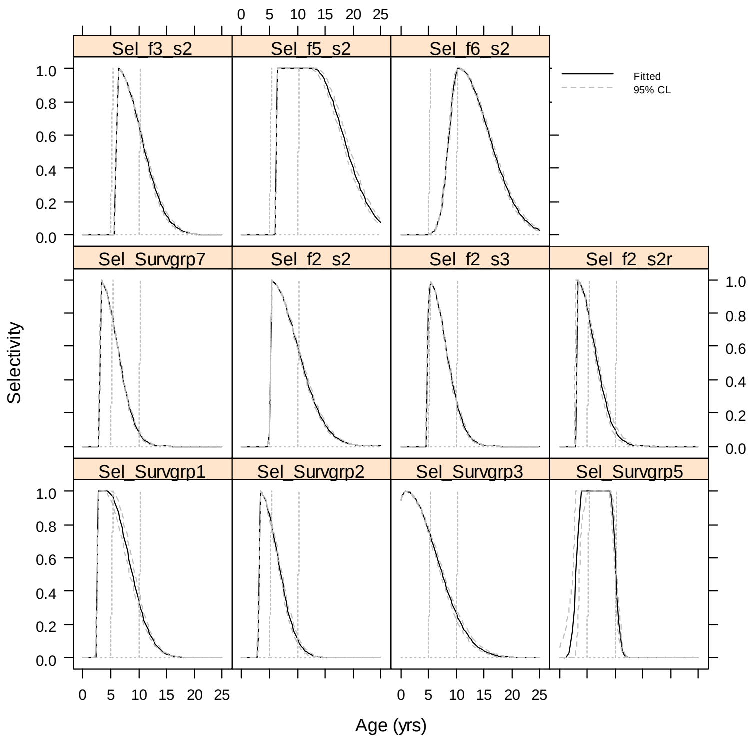


Figure 11: Fitted double-normal-plateau (DNP) and double-normal (DN) fishing selectivity curves showing showing 95% confidence bounds obtained from the MVN sample. Panel headings: Survgrp1 (survey years 2001, 2002, 2004, 2005, 2006, 2007), Survgrp2 (survey year 1999), Survgrp3 (survey year 1990), Survgrp5 (survey year 1993), Survgrp7 (survey year 2003), f2_s2, f2_s3 (trawl fishery Ground B, seasons 1, 2 and 3), f2_s2r (trawl fishery Ground B 2006, 2007 all seasons), f3_s2 (trawl fishery Ground C, all seasons), f5_s2 (longline fishery Ground C, season 2), f6_s2 (longline fishery Ground D, season 2). Reference lines are shown at ages 5 and 10.

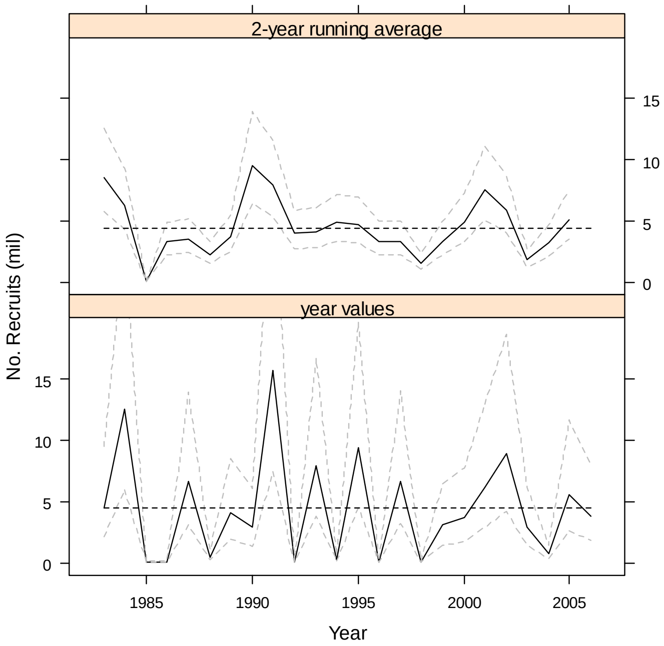
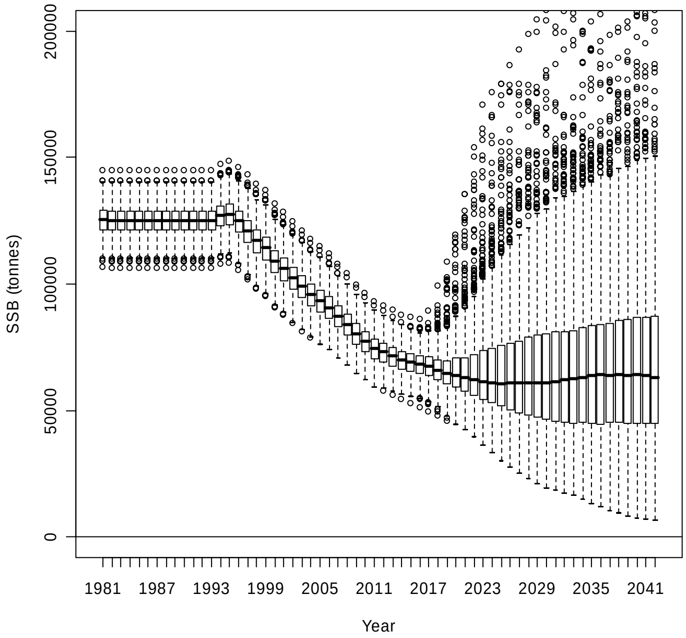


Figure 12: Comparison of age-1 recruitment series over historical survey period (1983–2006) showing approximate 95% confidence bounds (grey dashed lines). The black dashed line is set at the value of R_0. The lower panel shows year estimates from the fit of the LMM to MVN sample, while the top panel shows year estimates after a two-year running mean was applied to the MVN sample. Note that the year value for 1983 was intentionally set to the estimate of R_0 in the lower panel.

4.3 Estimation of yield

40. The estimated long-term yield was 2 500 tonnes with depletion probability of 0.081 and escapement probability of 0.505. Figure 13 shows box and whisker plots of spawning stock biomass (SSB), status of SSB (i.e. SSB/B_0) under random recruitments from 2005 onwards using the lognormal recruitment variability with a σ_R of 0.925 and a ρ of 0.361.

(a)



(b)

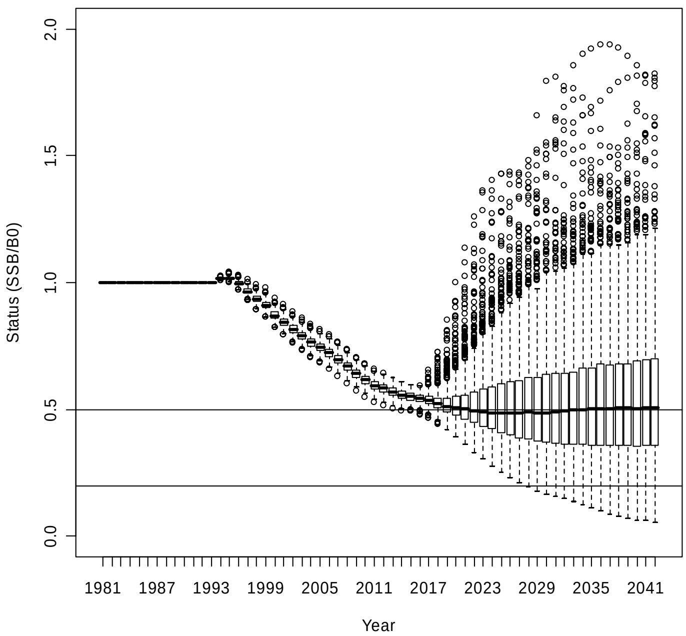


Figure 13: Projection results using future random lognormal recruitment from 2007 with an annual catch of 2 500 tonnes between 2008 and 2042. Each box represents the distribution of the variable across 1 000 projection trials for that year. (a) spawning stock biomass, (b) status of spawning stock biomass in a trial relative to B_0 in that projection trial (used in CCAMLR decision rules – lines show the 50% and 20% status levels for reference).

41. The Working Group agreed that the CASAL assessment provides a foundation for advice on stock status and yield for toothfish in this division. The CASAL assessment now takes better account of the potential differences in selectivities and *q*s of the different surveys. It also provides a better method for including data from the fishery. As such, the Working Group agreed that the estimate of yield from the CASAL assessment be used as a foundation for advice to the Scientific Committee.

4.4 Future research requirements

42. The Working Group noted the successful progress in developing an integrated assessment of *D. eleginoides* in CASAL. It agreed that further work could be undertaken to refine this assessment including examining:

(i) whether the model could be developed as a two-sex model;

(ii) whether improvement in the model structure can be made to allow the inclusion of tagging data in the assessment;

(iii) construction of age–length keys, if possible, as an alternative method for estimating densities of cohorts given the lack of defined modes in the length-density data;

(iv) optimal sampling schemes for establishing age–length keys.

5. By-catch of finfish and invertebrates

5.1 By-catch removals

43. By-catch removals for the toothfish fisheries (longline and trawl) are detailed in Table 10 from fine-scale data. By-catch in the toothfish trawl fisheries is generally low, comprising less than 1% of the total catch. Landed by-catch in the longline fisheries ranged from 6 to 13% of the total catch (10% in 2006/07) and including cut-offs revised these estimates to between 11 and 26% (21% in 2006/07) of the total catch. No species was caught in quantities approaching the catch limits.

Table 10: Catch history for by-catch species (macrourids, rajids, *Channichthys rhinoceratus*, *Lepidonotothen squamifrons* and other species), catch limits and number of rajids released alive in Division 58.5.2. Catch limits are for the division (see Conservation Measure 33-02 for details). (Source: fine-scale data.)

Season	Macrourids				Rajids				
	Catch limit (tonnes)	Reported catch (tonnes)			Catch limit (tonnes)	Reported catch (tonnes)			Number released
		Longline	Trawl	Total		Longline	Trawl	Total	
1996/97	-	0	0	0	-	0	3	3	-
1997/98	-	0	0	0	120	0	3	3	-
1998/99	-	0	1	1	-	0	2	2	-
1999/00	-	0	4	4	-	0	6	6	-
2000/01	-	0	1	1	50	0	5	5	-
2001/02	50	0	4	4	50	0	4	4	-
2002/03	465	3	1	4	120	7	27	33	-
2003/04	360	42	3	46	120	62	14	76	155
2004/05	360	72	2	74	120	71	8	79	8412
2005/06	360	26	1	27	120	17	19	35	3814
2006/07	360	61	4	65	120	8	6	15	7886

Season	*Channichthys rhinoceratus*				*Lepidonotothen squamifrons*			
	Catch limit (tonnes)	Reported catch (tonnes)			Catch limit (tonnes)	Reported catch (tonnes)		
		Longline	Trawl	Total		Longline	Trawl	Total
1996/97	-	0	2	2	-	0	0	0
1997/98	80	0	2	2	325	0	3	3
1998/99	150	0	1	1	80	0	0	0
1999/00	150	0	3	3	80	0	0	0
2000/01	150	0	1	1	80	0	4	4
2001/02	150	0	4	4	80	0	1	1
2002/03	150	0	21	21	80	0	0	0
2003/04	150	0	7	7	80	0	3	3
2004/05	150	0	36	36	80	0	2	2
2005/06	150	0	32	32	80	0	5	5
2006/07	150	0	10	10	80	0	8	8

Season	Other species			
	Catch limit (tonnes)	Reported catch (tonnes)		
		Longline	Trawl	Total
1996/97	50	0	6	6
1997/98	50	0	3	3
1998/99	50	0	3	3
1999/00	50	0	5	5
2000/01	50	0	6	6
2001/02	50	0	10	10
2002/03	50	0	10	10
2003/04	50	3	16	19
2004/05	50	3	9	12
2005/06	50	3	7	12
2006/07	50	1	3	4

5.2 Assessments of impact on affected populations

44. Updated length–weight relationships, length-at-maturity data and estimates of abundance from survey data for rajids were presented in WG-FSA-05/70. Insufficient information was available to update assessments.

45. No stock assessments of individual by-catch species were undertaken in 2007. By-catch limits of *Channichthys rhinoceratus* and *Lepidonotothen squamifrons* are based on assessments carried out in 1998 (SC-CAMLR-XVII, Annex 5, paragraphs 4.204 to 4.206) and by-catch limits of the grenadier *Macrourus carinatus* are based on assessments carried out in 2002 and 2003 (SC-CAMLR-XXII, Annex 5, paragraphs 5.245 to 5.249).

5.3 Mitigation measures

46. The fishery operates under Conservation Measure 33-02.

47. The Working Group recommended that, where possible, all rajids should be cut from the line while still in the water, except on the request of the scientific observers during their sampling period.

6. By-catch of birds and marine mammals

48. No seabird mortality has been reported in the five years to date of longline fishing in Division 58.5.2. Seabird/trawl interactions are reported in Table 11. Two Cape petrels were observed killed in the Division 58.5.2 toothfish trawl fishery in 2006/07 (SC-CAMLR-XXVI, Annex 6, Part II, paragraphs 41 and 43).

Table 11: Seabird mortality totals and rates (BPT: birds/trawl) and species composition of by-catch, recorded by observers in Division 58.5.2 trawl fisheries over the last six seasons. DIM – black-browed albatross; PRO – white-chinned petrel; DAC – Cape petrel (data from SC-CAMLR-XXVI, Annex 6, Part II, Table 11).

Season	Target species	BPT	Dead			Total dead	Alive (all species combined)
			DIM	PRO	DAC		
2000/01	*D. eleginoides*	<0.10				0	0
2001/02	*D. eleginoides*	<0.10				0	1
2002/03	*D. eleginoides*	<0.10	2	2	2	6	11
2003/04	*D. eleginoides*	<0.10				0	13
2004/05	*D. eleginoides*	<0.11	5	3		8	0
2005/06	*D. eleginoides*	0.00				0	0
2006/07	*D. eleginoides*	<0.10			2	2	0

49. In 2003/04 three fur seals were killed when the *Austral Leader* (trawl fishery) was targeting toothfish.

50. In 2004/05 three elephant seal mortalities were reported in the longline fishery for toothfish (SC-CAMLR-XXIV, Annex 5, paragraph 7.47) and there was a single fur seal caught and released alive in the toothfish trawl fishery (SC-CAMLR-XXIV, Annex 5, Appendix O, paragraph 216).

51. In 2005/06 one Antarctic fur seal was reported entangled and released alive in the longline fishery and one leopard seal was caught and killed in the trawl fishery. No marine mammal mortalities were reported in the Division 58.5.2 toothfish trawl fishery in 2006/07, and one southern elephant seal mortality was observed in the longline fishery in 2006/07 (SC-CAMLR-XXVI, Annex 6, Part II, paragraphs 41 and 43).

6.1 Mitigation measures

52. Longline fishing is conducted in accordance with Conservation Measures 24-02 and 25-02 and the special requirements outlined in Conservation Measure 41-08, paragraph 3; trawl fishing in accordance with Conservation Measure 25-03.

7. Ecosystem implications/effects

53. Fishing gear deployed on the seabed can have negative effects on sensitive benthic communities. The potential impacts of fishing gear on the benthic communities in Division 58.5.2 are limited by the small size and number of commercial trawl grounds and the protection of large representative areas of sensitive benthic habitats from direct effects of fishing in an IUCN category Ia marine reserve (SC-CAMLR-XXI/BG/18). The marine reserve and associated conservation zone comprises around 17% of the area of the Australian EEZ around Heard Island and McDonald Islands and falls entirely within CCAMLR Division 58.5.2.

54. The Working Group noted that by-catch of benthos was monitored by observers in the early stages of the development of the fishery and that by-catch of benthos was much lower in areas that have subsequently become the main fishing grounds.

8. Harvest controls and management advice

8.1 Conservation measures

55. The limits on the fishery for *D. eleginoides* in Division 58.5.2 are defined in Conservation Measure 41-08. The limits in force in 2006/07 and the Working Group’s advice to the Scientific Committee for the forthcoming 2007/08 season are summarised in Table 12.

Table 12: Limits on the exploratory fishery for *D. eleginoides* in Division 58.5.2 in 2006/07 (Conservation Measure 41-08) and advice to the Scientific Committee for 2007/08.

Element	Limit in 2006/07	Advice for 2007/08
Access (gear)	Trawls or longlines or pots	
Catch limit	2 427 tonnes west of 79°20'E (see CM 32-14)	Review
Season:		
trawl	1 December to 30 November	Same period
longline	1 May to 31 August, with possible extension to 30 September for any vessel that has demonstrated full compliance with CM 25-02 in the 2005/06 season.	Review
By-catch	Fishing shall cease if the by-catch limit of any species, as set out in CM 33-02, is reached.	Carry forward
Mitigation	In accordance with CMs 24-02, 25-02 and 25-03.	Carry forward
Observers	Each vessel to carry at least one scientific observer and may include one additional CCAMLR scientific observer.	Carry forward
Data	Ten-day reporting system as in Annex 41-08/A Monthly fine-scale reporting system as in Annex 41-08/A on haul-by-haul basis. Fine-scale reporting system as in Annex 42-02/B. Reported in accordance with the Scheme of International Scientific Observation.	Carry forward
Target species	For the purpose of Annex 41-08/A, the target species is *Dissostichus eleginoides* and the by-catch is any species other than *D. eleginoides.*	Carry forward
Jellymeat	Number and weight of fish discarded, including those with jellymeat condition, to be reported. These catches count towards the catch limit.	Carry forward
Environmental protection	Regulated by CM 26-01.	Carry forward

8.2 Management advice

56. The Working Group recommended that the catch limit for *D. eleginoides* in Division 58.5.2 west of 79°20'E should be 2 500 tonnes for the 2007/08 fishing season.

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Williams, R., G.N. Tuck, A.J. Constable and T. Lamb. 2002. Movement, growth and available abundance to the fishery of *Dissostichus eleginoides* Smitt, 1898 at Heard Island, derived from tagging experiments. *CCAMLR Science*, 9: 33–48.